SEGMENTAL COORDINATION AND TEMPORAL STRUCTURE OF THE VOLLEYBALL SPIKE

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In the game of volleyball, the spike is one of the most difficult and demanding techniques to master. The athlete is expect4ed to jump and hit a ball with maximum force and accuracy at the approximate peak of the jump. Prsala (1982) identified four phases in the analysis of the spike: the approach, preparation, hitting, and landing. The approach involves two or three controlled running strides, a transitional last step to prepare for the transfer of horizontal momentum to vertical momentum, and a two foot vertical jump. In the preparatory phase the striking arm is swung upward in an abducted and laterally rotated position. The elbow is flexed at approximately 90 degrees and the wrist hyperextended. During the hitting phase, the shoulder is elevated; the upper arm is inwardly rotated and adducted; the forearm is extended at the elbow and the wrist is flexed. The athlete absorbs the downward momentum by flexing the joints of the lower extremities when landing.

Upon review of the literature, it became apparent that a quantitative analysis that investigated the proper sequential action and timing patterns of the hitting phase of the volleyball spike was needed. The purpose of this investigation was to distinguish the timing pattern(s) of the sequential action of the volleyball spike.

Methodology

Subjects

Fifty female college age volleyball players served as subjects for this investigation. The subjects represented top teams from 14 institutions and were diverse in their physical abilities. All subjects were requested to attempt the spiking pattern regardless of the position they played on their teams. Several anthropometrical measures as well as demographic data were collected from each of the subjects.

Procedures

Film records were obtained with a 16 mm Locam high speed motion picture camera operating at a speed of 200 frames per second. The camera was positioned perpendicular to the net in order to capture the sagittal view of the subject during the spiking performance. The camera was positioned 9 m from the performer and was equipped with a 50-120 mm Angineaux lens. Each subject was filmed repeatedly until a successful trial of the spike was recorded. A successful spike was defined as placing the ball in the legal boundary lines of the court without the subject touching the net or going over the centerline. The volleyball was suspended by a hanging device above the net to eliminate setter placement errors. Prior to the actual trials for data collection, subjects were permitted to practice with the ball suspended at different heights above the net until a suitable height was found.

The film records were projected onto a horizontal surface with a Lafayette motion picture analyzer. Spatial coordinates were digitized with a Numonics Model 1224 digitizer interfaced directly to an Apple 1le microcomputer and were further analyzed with software written by Richards and Wilkerson (1984). Consecutive frames were digitized from the start of the preparatory phase until the follow through of the spiking action was completed. The raw data were smoothed with a Butterworth second-order low-pass digital filter set a 14 Hz according to Winter (1982).

Selection of Variables

The specific variables analyzed were ball velocity, angle of ball trajectory, and absolute angles of the trunk, upper arm forearm, and hand from the right horizontal in a counterclockwise direction. Additionally, the angular displacements, velocities, and accelerations were analyzed for the purpose of determining the positive contribution of each segment to the movement. According to Hudson (1982), the positive contribution is defined as point in time when the segment begins to open (extend) consistently in the direction of the desired action until the maximum angular acceleration occurs. The temporal patterns of the segments relative to each other were also analyzed.

Evaluation of Data

Descriptive means, standard deviations, and ranges of all variables were calculated and evaluated. Specific relationships among variables were analyzed through the use of a Pearson Product Moment Correlation with an alpha of .01. Styles of hitting were compared through the use of a one-way mulivariate analysis of variance (MANOVA). The alpha level was set at a .05 and a Tukey post-hoc test was performed where significance was indicated.

Results and Discussion

Subjects

The subjects of this study had mean age of 18.96 years (± 1.09), a height of 171.64 cm (± 6.18), and weight of 63.51 kg (± 8.17). Anthropometric measures of the subjects were a bicep diameter of 28.98 cm (±2.55), arm length of 72.57 cm (± 3.95), tricep skinfold of 16.62 (± 4.63), and an iliac skinfold of 11.10 (± 4.63). The body density of each subject was calculated with the above measures to reveal a mean of 1.0526 (+ .008). The demographic and anthropometric measures in this study were very similar to those in other research studies of female collegiate volleyball players and female athletes in general (Hosler, Morrow, & Jackson, 1978; Kovaleski, Parr, Hornak, & Roitman, 1980).

Ball Parameters and Hitting Style

The mean ball velocity for all 50 subjects was 13.8 m/s (± 3.1). The ball angle of trajectory mean was 82.4 degrees (± 8.4), which represents 7.6 degrees below the horizontal. Other research studies which have reported similar values were completed by Love (1978) and Blackman (1968). Ball velocities reported by Love and Blackman were 14 to 16 m/s with angles of trajectory ranging from 7.8 to 25.3 degrees below the horizontal.

Similar to the findings of Oka, Okamoto, and Kumanmoto (1975), two distinct patterns of hitting were observed. In this study, 15 subjects demonstrated the backswing style, in which the humerus is swung below or level with the horizontal during backswing. Thirty-five subjects demonstrated the elevation style, in which the spiker's humerus is elevated in a diagonal lateral direction above the horizontal. The subjects in this study exhibiting the backswing style had a mean ball velocity of 14.03 m/s (± 3.04) with a range of 8.89 to 18.42 m/s. The elevation style had a mean ball velocity of 12.28 m/s (± 3.19) with a range of 6.98 to 21.02 m/s. The ball angle of trajectory means were 77.63 degrees (± 7.05) and 84.14 degrees (± 10.15) for the backswing and elevation styles respectively. The backswing ball angle of trajectory range was from 68.84 to 90.63 degrees. The elevation ball angle of trajectory range was from 63.34 to 99.99 degrees.

Temporal Analysis

The temporal pattern was divided into a preparatory and action (hitting) phase as defined by Prsala (1982). The actual time, and percentage of total time for each phase was evaluated. The means, standard deviations, and ranges for these temporal variables are presented in Table 1.

Table 1. Temporal factors

	Backswing			Elevation		
	Mean	SD	Range	Mean	SD	Range
Preparation Time	.144	.037	.08-.20	.131	.026	.09-.18
Preparation Percent	44	10.56	26-60	44	6.10	30-56
Action Time	.185	.047	.10-.26	.167	.029	.11-.24
Action Percent	56	10.56	40-74	56	6.10	44-70
Total Time	.329	.052	.23-.44	.298	.041	.22-.38

The backswing style of hitting takes slightly longer to execute than the elevation style. One interesting fact was that regardless of the style of hitting or length of time for the skill, the percentage of time utilized for preparation and action remained constant. Regardless of the sstyle of hitting, the preparation occupied 44 percent of the total time and the action phase occupied 56 percent of the total time. The two styles were comparable in proportions of the time spent in preparation and action.

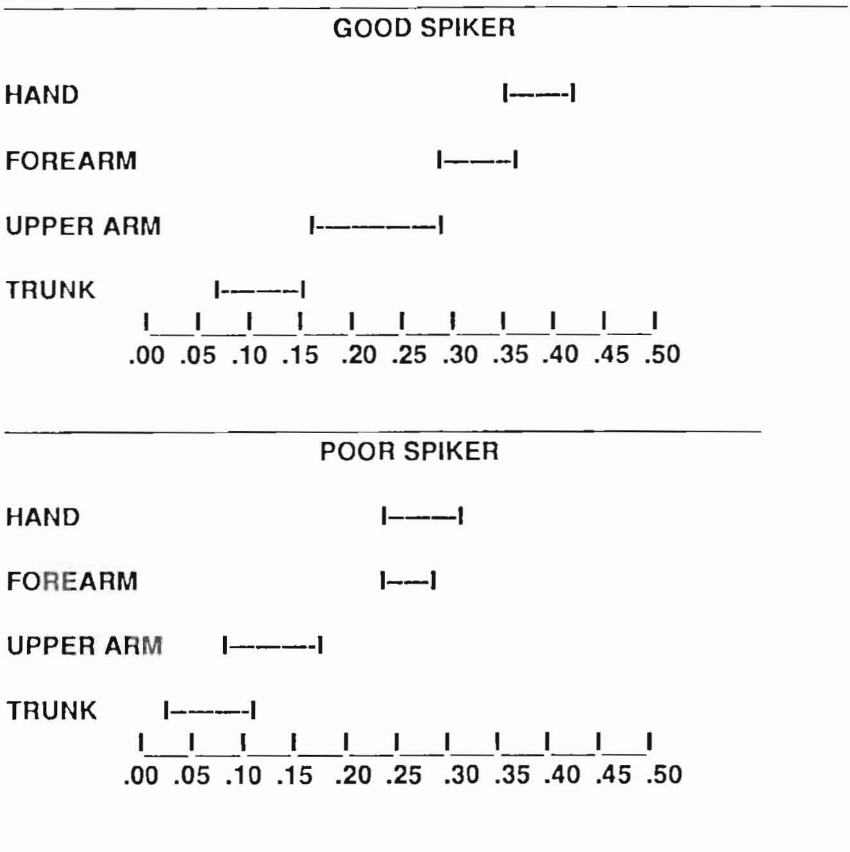
Segmental Contributions and Patterns

In 1982, Maxwell used 15 subjects from the Canadian Women's Junior National Team to determine patterns among good spikers. Good spikers showed a smoothness of movement throughout the entire psike. Additionally, Alexander & Seaborn (1982) and Prsala (1982) suggested that spiking is a sequential action. The rotating trunk brings the shoulder and upper arm through first while the forearm and hand follow later. This creates a whip-like action by stopping the proximal end and transferring the momentun to the smaller more distal ends thereby increasing the linear velocity. The success of this action depends on the correct timing of the joint actions. Review of the background information suggests that an investigation into the proper sequential action and timing patterns of the volleyball spike was needed. Hudson (1986) examined the overlap between adjacent segments during their positive contribution. (The positive contribution was defined as the time from initiation of segment extension until maximum angular acceleration.) The greater the overlap between adjacent segments in the movement, the more simultaneous the pattern. The smaller the overlap between adjacent segments, the more sequential the movement pattern. According to Hudson (1982), the sequential joint actions with little overlap would be required by skills of high movement velocities such as kicking, overarm throwing, and volleyball spiking. Regardless of the style of hitting by the subjects of this study, the pattern was generally sequential.

The segmental times of positive contribution by the trunk, upper arm, forearm, and hand are presented in Table 2. The times of contribution are smaller as the movement progresses from the most proximal part of the body (trunk) to the most distal part (hand) in the backswing style. The elevation style does not show this type of progression. The maximum velocities are larger in the forearm and hand of the elevation style as opposed to the backswing style although the backswing style although the backswing style has a larger mean ball velocity. The trunk and upper arm maximum velocities are comparable in the two styles of hitting.

presented in Figure 1.

Figure 1. Segmental overlap of good and poor spikers



A MANOVA was performed on the styles of hitting versus the kinematic variables of the pike. There was a significant difference betwen the two styles of hitting ($F(9,40) = 2.16$, $p < .05$). A tukey post-hoc test was performed to determine which variables were significantly different between the two styles of hitting. The only significance was ball angle ($F = 5.09$, $p < .05$). The backswing style of hitting produced the more acute angle of ball trajectory.

Conclusions

The physical characteristics of the subjects and ball parameter statistics of this study were similar to those of other female collegiate volleyball players. Two distinct styles of hitting were identifiable. The elevation style has been identified by Maxwell (1982) as the preferred style among women, but the backswing style generally produces the greater velocity and more acute angle of ball trajectory.

It appeared that the percentage of time to be utilized in preparation and action remains constant regardless of the skill total time or the hitting style. All subjects generally demonstrated a sequential timing pattern, but differences were noted among the good and poor spikers. The good spikers demonstrated a more pure form of the sequential timing pattern than did the poor spikers. The poor spikers who were all using the elevation style, demonstrated a pause and/or larger overlaps in positive contributions of two sets of adjacent segments (trunk/upper arm and forearm/hand). Good spikers had larger maximum accelerations of the forearm and hand. The timing pattern utilized by the poor spikers (elevation style) either helps to distinguish between the two styles of hitting and/or helps to explain the difficulty these spikers have in coordination or timing.

Further study is susggested in comparing the two styles of hitting for women volleyball players. A larger and more equally distributed sample between styles of hitting might further help clarify significant differences between the styles. Further study would be necessary to reveal the merits of the two styles and the application of the best style in the practical setting.

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